



# **DOE OETD GridWorks RD&D Planning Workshop**

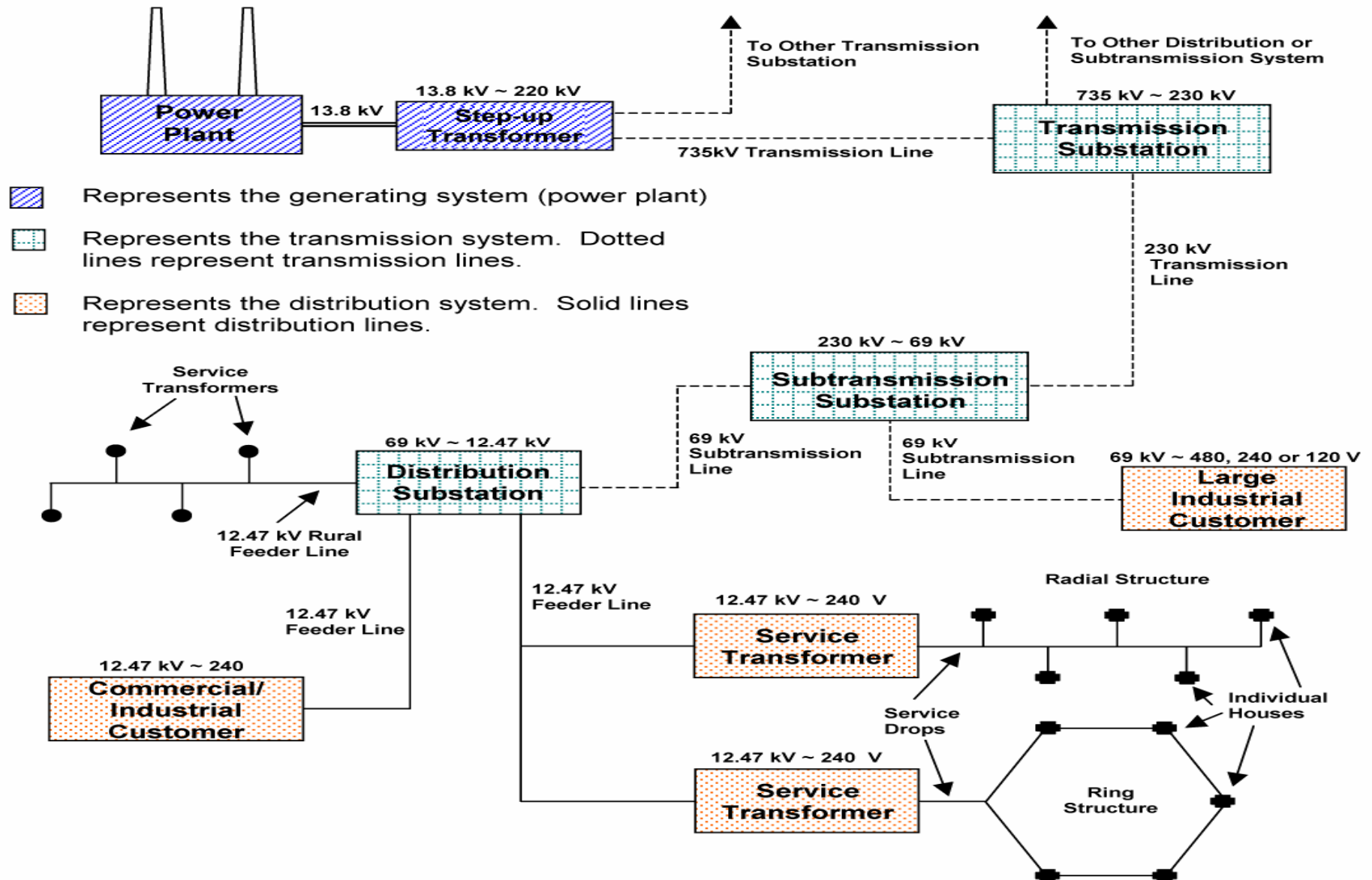
**(Hyatt Regency O'Hare Airport Hotel, Rosemont, Illinois)**

## **National Laboratory/University Perspective on Existing RD&D**

**“Research Pathways to the Next Generation of Equipment  
for  
Substations and the Grid”**

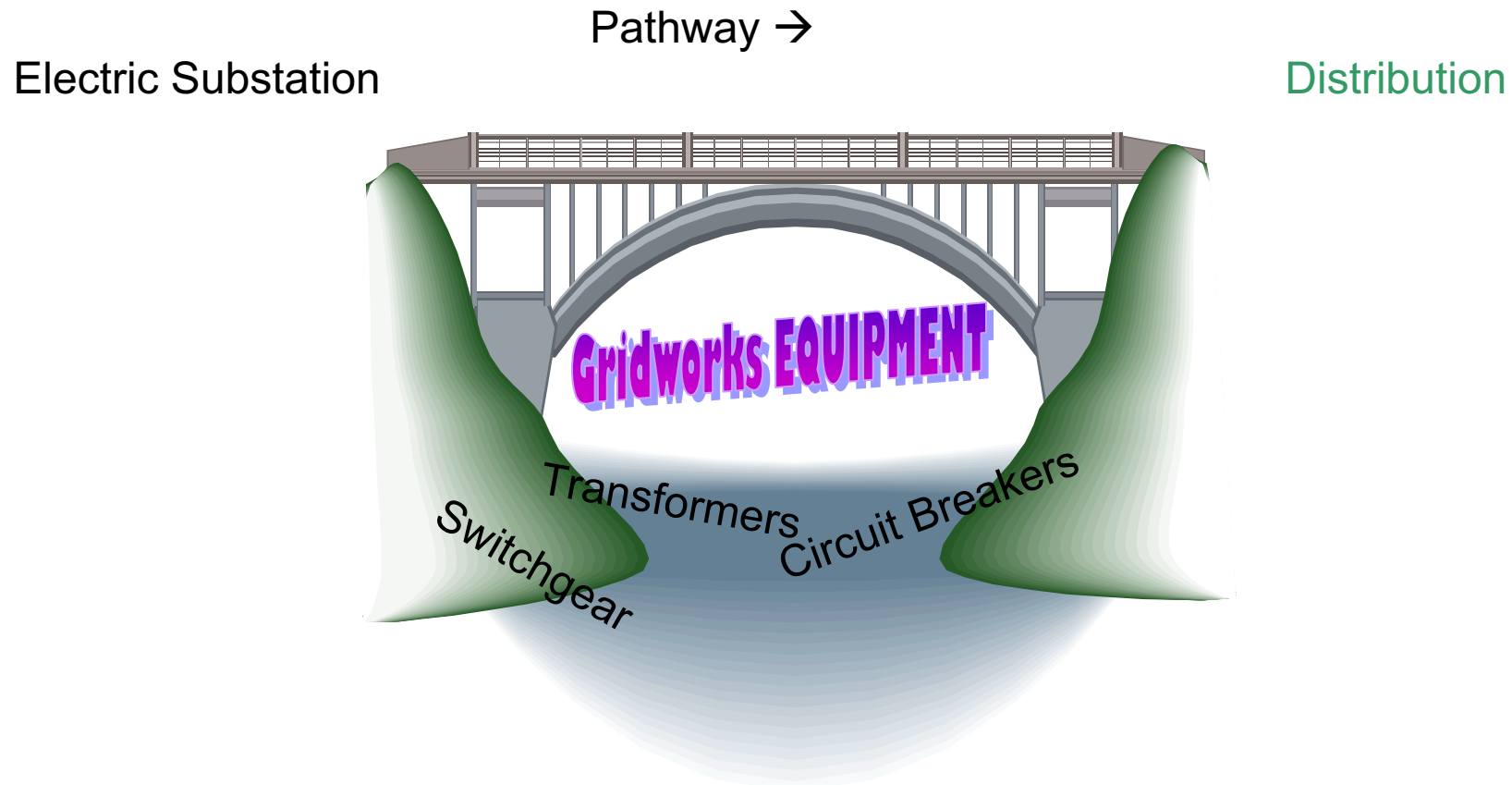
**Panel #3 – Technical Status of Substation and Protective Systems  
(e.g., transformers, switchgear, circuit breakers, surge arresters)**

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National Renewable Energy Laboratory  
Golden, Colorado  
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## GridWorks Equipment Approach





Central Power Plant



Transformers



Substation





## Substations from 13.5KV to 500KV





## **Electric Substation Designs – Today**

**Air Insulated Substation (AIS)** - Six types of bus/switching (reliability) arrangements commonly used in AIS designs. Single bus; double bus, double breaker, main and transfer bus; double bus and single breaker; ring bus; and breaker and a half. (Developed over 100 years ago - operates in meter space of air insulation and can be up to 10 times greater in space used than GIS in size)

**Gas Insulated Substation (GIS) SF<sub>6</sub>** – Sulfur Hexafluoride - Inert gas)  
(Enclosed Module includes: circuit breaker, current transformers, voltage transformers, disconnect and ground switches, interconnecting bus, surge arresters, and connections to the rest of the electric power system)(operates in centimeter space and small areas)  
(Developed between 1968 to 1972)(green house gas -- environmental issues-global warming)



## **Electric Substation Functions for the Electric Power System**

- 1.Voltage change from one level to another
- 2.Voltage regulated to compensate for system voltage change
- 3.Electric transmission and distribution circuits switched into and out of the system
- 4.Electric power qualities flowing in the transmission and distribution circuits measured
- 5.Communication signals connected to the circuits
- 6.Lightning and switching surges eliminated from electric system
- 7.Electric generators connected to the transmission and distribution system
- 8.Interconnection between the electric systems of various companies completed
- 9.Reactive kilo-volt-amperes supplied to the transmission and distribution circuits and the flow of reactive kilo-volt-amperes on the transmission and distribution circuits controlled.





## **Substation Equipment – Major Components**

Concrete Foundations

Duct runs

Manholes

Steel superstructure

Bus support insulators

Suspension insulators

Lightning arresters

SF6 circuit breakers

Oil circuit breakers

Air circuit breakers

Vacuum circuit breakers

Circuit switchers

Disconnect switches

Power transformers

Coupling capacitors

Potential transformers

Current transformers

High-voltage fuses

High-voltage cables

Rectifiers

Frequency changers

Pothead

Metal-clad switchgear

Shunt reactors

Capacitors

Synchronous condensers

Grounding transformers

Grounding resistors

Control house

Control panels

Meters

Relays

Supervisory control

Microwave

Power-line carrier

Batteries

Battery chargers

Conduits

Control wires





## **Some Electric Substation Consideration**

GIS and AIS substation designs  
Switching equipment  
Automation  
Containment (oil, gas)  
Community  
Animal Deterrents  
Security (e.g., analysis, etc.)  
Grounding  
Grounding and Lightning  
Seismic  
Fire protection (e.g., analysis, etc.)  
Economics  
Safety (e.g. analysis, etc.)  
Reliability (e.g., analysis, etc.)



## Equipment/System RD&D Status and Needs

- . Electric Substation RD&D by DOE/National Laboratories (limited with focus on power electronics and analysis)
- . Means to extend substation reliability and life (some **EPRI** studies)
- . RD&D by the electric power industry means up-grades by some (limited innovation)
- . Most RD&D on substations not being done by electric utilities as in the past (**PSERC** at (<http://www.pserc.org>) for university power systems R&D supporting industry)
- . Component/equipment /systems approach needed (multi-functional Substation)
- . Electro-mechanical to Digital control/protection systems (slow in coming)
- . Semi-conductor power devices – new higher power and operating temperatures
- . Distributed Generation (micro and macro grid operation needs to be proven)
- . Advanced materials for conductors , motors, and transformers (e.g., HTS)
- . Distribution substation and protection engineers – expertise gap in the making
- . Training – education of power electrical engineers critical – crisis in the making
- . Probabilistic Analysis (BNL)-Con Edison Substation communication interdependency
- . Is it true that some Substations are over 75 years ?



## Advanced Substation Technologies/Systems

- . Solid State Substation including a variety of solid state devices: circuit breakers, transformers, voltage/current measurements, electronic protection/metering, fault current limiter – some work proposed or started by **EPRI**)
- . Substation operating onsite power alternatives to lead acid batteries: i.e., DG, FC, etc..
- . Grounding systems – optimize/reduce corrosion/increase fault current capacity, etc..
- . Modular Substations – a step beyond standardized designs/flexible
- . Substation Pad designs (drop and move)
- . Mobile Pad designs (move and move)
- . Blending Substation into its environment – underground, in buildings, etc..
- . Single Failure criteria system design for reliability **(NREL)**
- . **IEEE P1547.5 Draft Technical Guidelines for Interconnection of Electric Power Sources Greater than 10MVA to the Power Transmission Grid**
- . Distributed Power Substations (self contained power switch-able micro/macro-grid)





## GridWorks Systems Approach

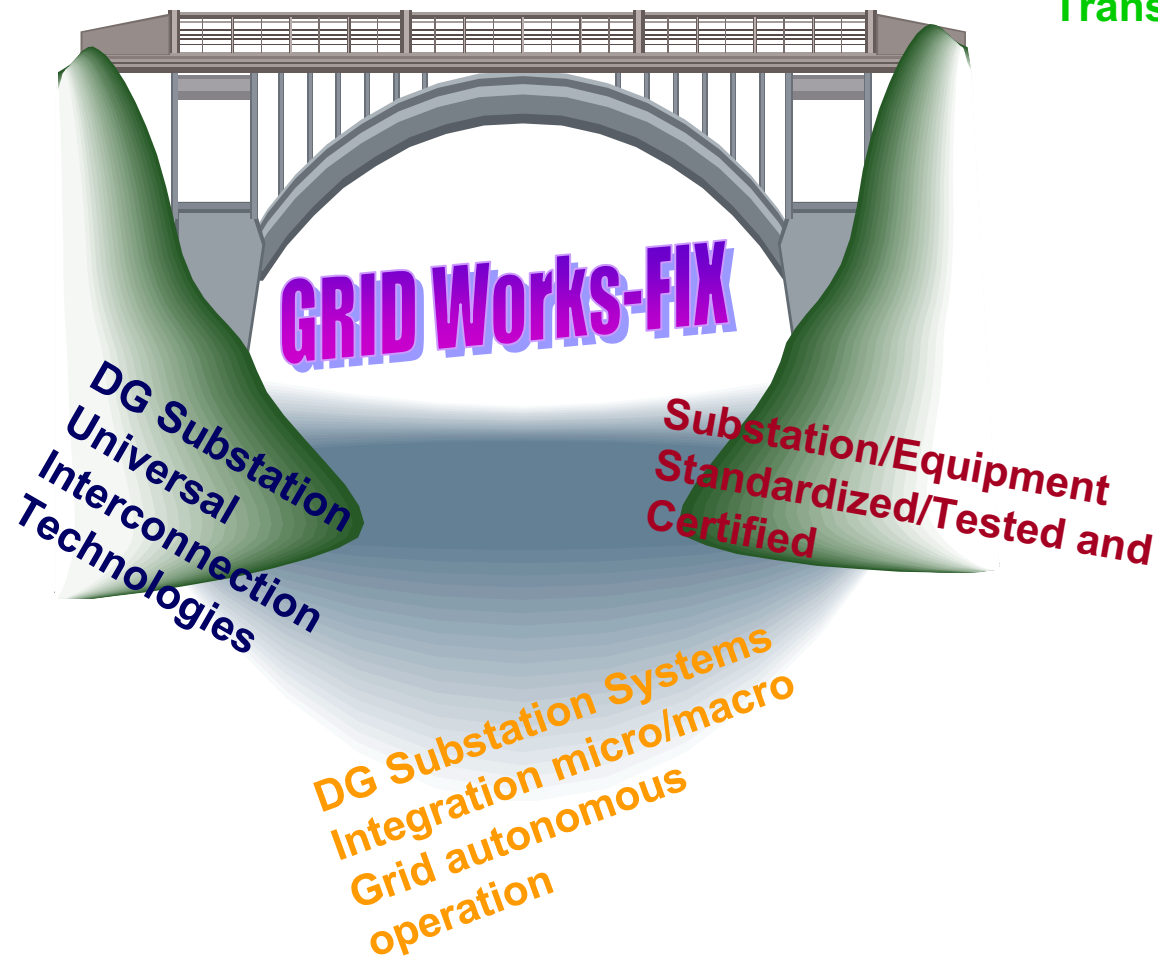
OETD/Distribution

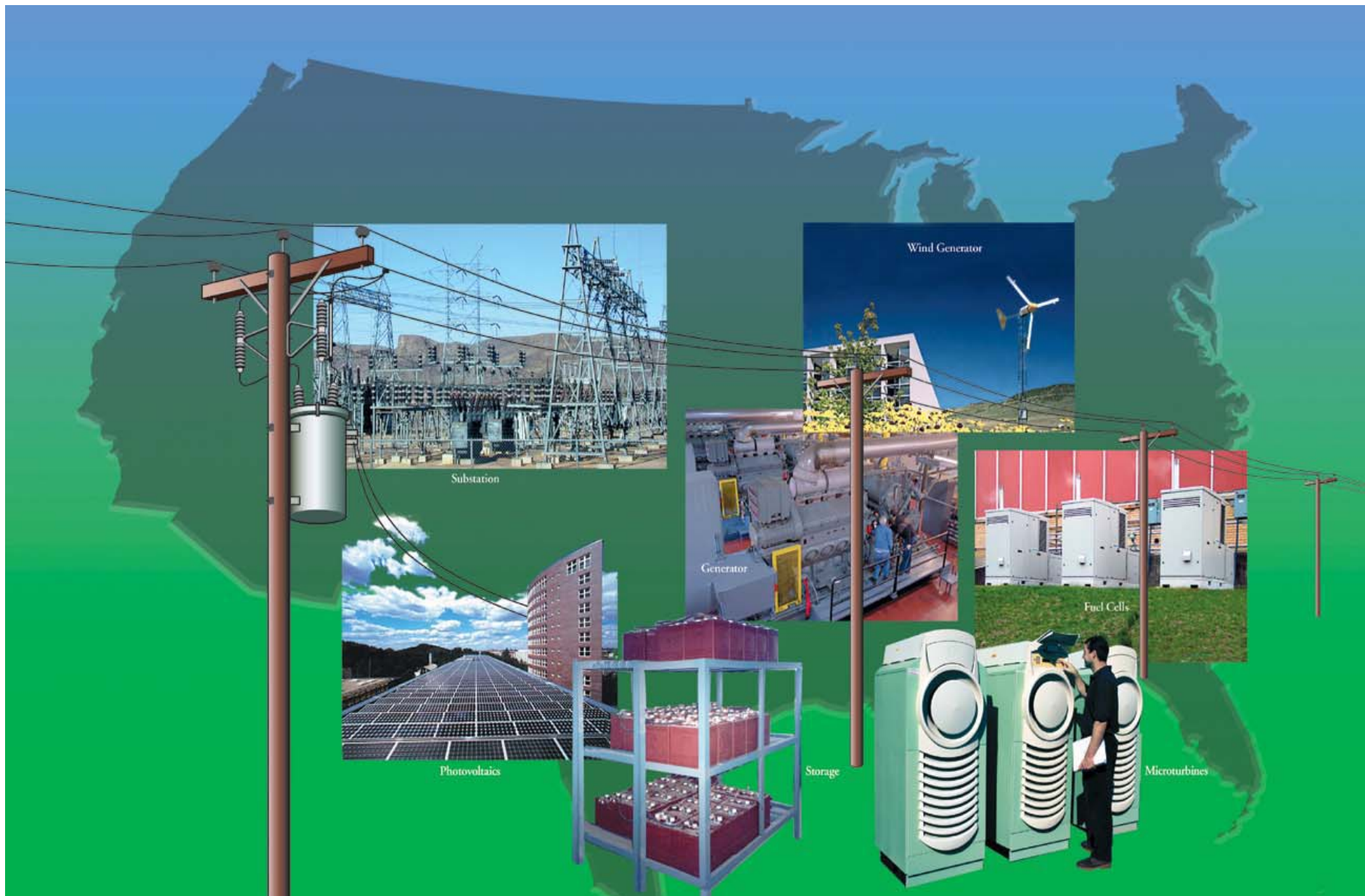
OETD/Transmission

Substation  
Distribution

Advanced Substation  
Electric Reliability →

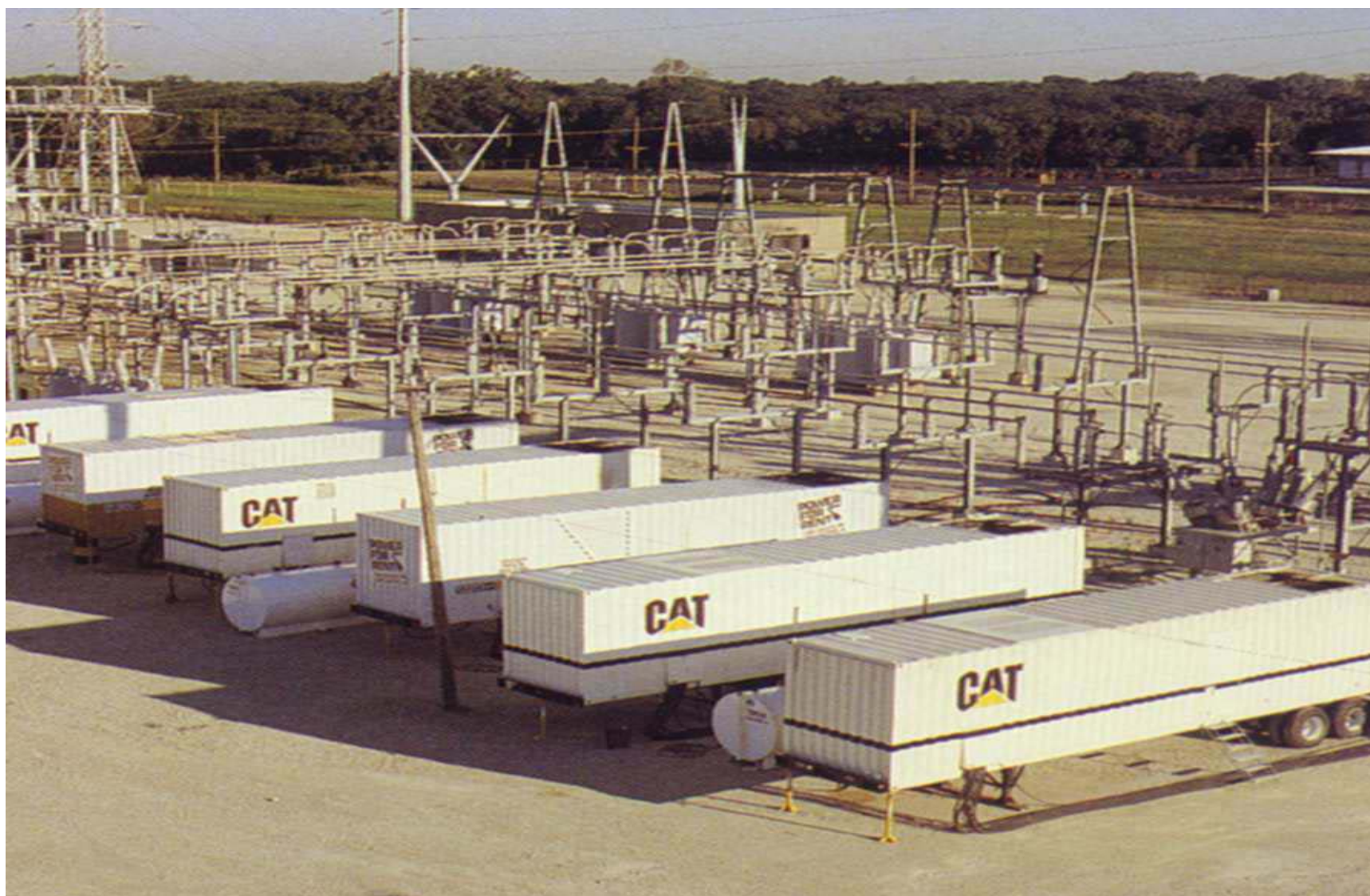
Substation  
Transmission







## DG/Substation (Macro-GridWorks)

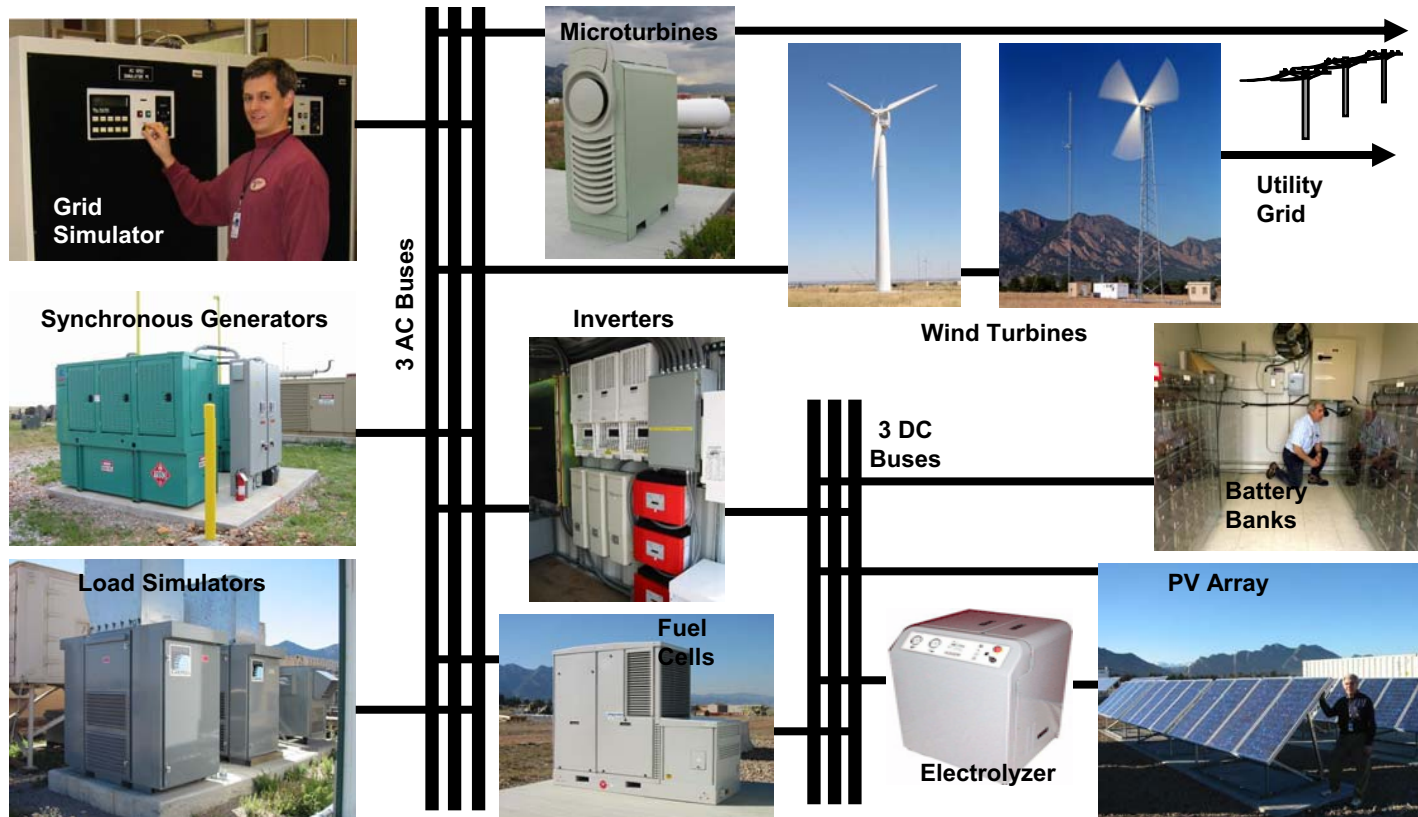






## NREL DER Test Facility

### NREL Substation and DG Equipment Testing



- Currently operational
- Test Systems up to 200kW
- Natural Gas on site
- All DE Technologies





# GRIDWORKS RD&D Pathways

## A Broader Perspective

### Equipment Approach

(advanced materials, devices, components)

and

### Systems Approach

(DGs, Distribution /Micro grids ,and Substation/Macro grids)